

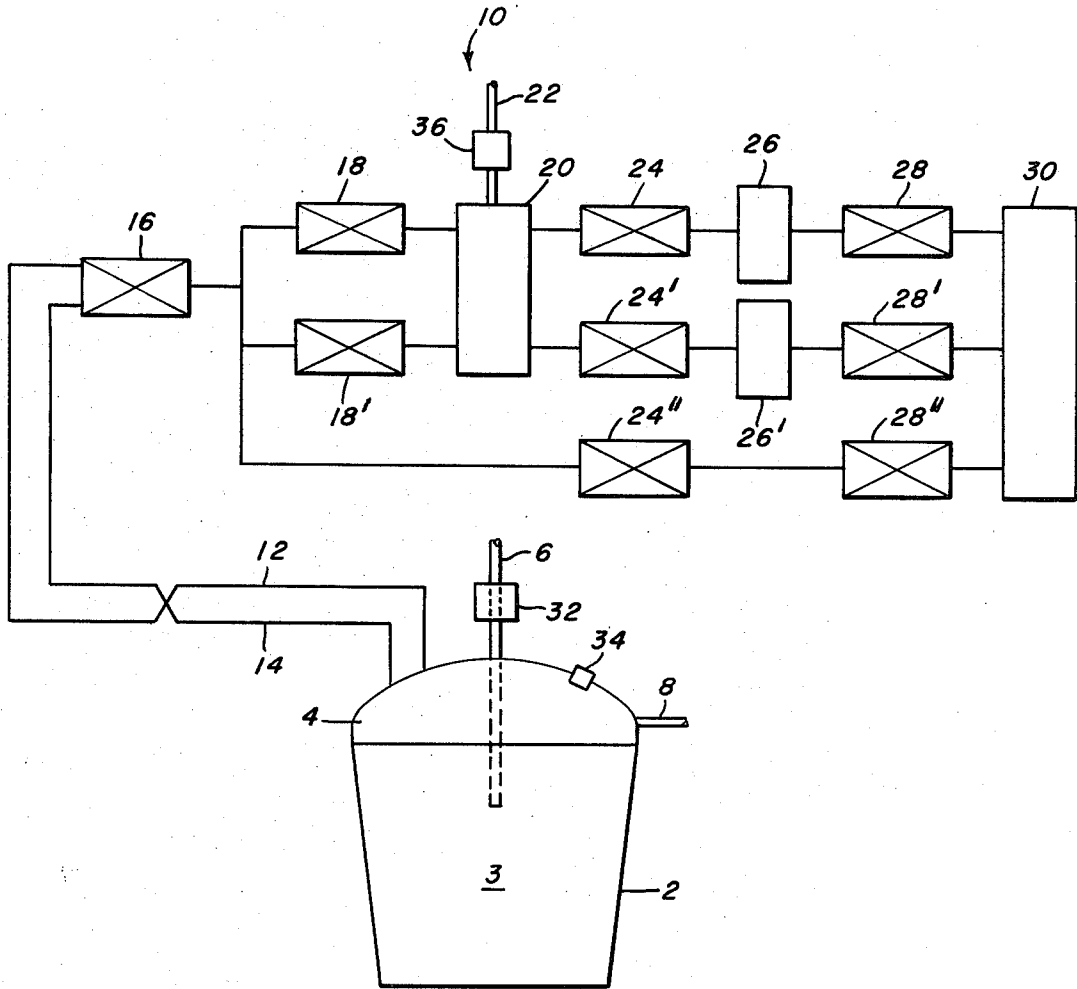
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3,700,429

METHOD OF CONTROLLING VACUUM DECARBURIZATION

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## METHOD OF CONTROLLING VACUUM DECARBURIZATION

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4 Claims

### ABSTRACT OF THE DISCLOSURE

A method of controlling vacuum decarburization of molten steel wherein the ambient pressure within the vessel within which the decarburization is being performed is monitored and compared with an expected pressure calculated from known decarburization reaction parameters to reflect the effectiveness of the decarburization process and the pressure within the vessel or inputs to the reaction are readjusted in order to establish an efficient decarburization reaction while minimizing the oxidation of desired metallic values within the steel.

### BACKGROUND OF THE INVENTION

This invention relates to the process control of molten metal vacuum decarburization systems where the low pressure (subatmospheric) and a mixture of oxidizing and/or inert gases are used to minimize metallic oxidation. The term "vacuum decarburization" as used herein refers to decarburization systems using subatmospheric pressure. The use of low pressure to promote decarburization of steel and its alloys is well known. U.S. Pat. No. 2,040,566 suggests that alloy steel may be decarburized under vacuum without the oxidation of metallics. However, in spite of these teachings, vacuum decarburization has not become a commercial process for the decarburization of steels. It is suggested that lack of a responsive method of controlling the reaction has prevented commercial exploitation of the vacuum decarburization process.

In recent years the advent of high capacity steam ejector systems have made available economic vacuum pumping systems suited for use in steel making areas. Full utilization of this equipment and realization of a commercial vacuum decarburization process awaits the development of a sound control system which minimizes metallic oxidation in the process. A previous invention of mine, disclosing a method for dynamic controlling the decarburization of steel and disclosed in U.S. Patent 3,594,155, issued July 20, 1971, teaches a method of control of the decarburization process while minimizing metallic oxidation. My present invention hereinafter described teaches improvements in the dynamic control of decarburization of steel wherein this decarburization is accomplished in a vacuum environment.

### SUMMARY OF THE INVENTION

A method of decarburizing molten metal such as steel within a closed vessel under a vacuum, wherein the oxidizing material is introduced into the vessel and wherein it is desired to avoid the oxidation of certain metal values contained within the metal bath according to the following operative steps:

- (1) Measuring the composition and flow rate of input gases to the closed vessel.
- (2) Measuring the composition of off gases from the closed vessel, and determining the expected rate of carbon removal from the steel.

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- (3) Determining the expected ambient pressure within the closed vessel.
- (4) Measuring the actual pressure within the closed vessel and adjusting the composition and flow rates of the input and off gases to maintain the actual pressure within the vessel at least as great as the expected pressure within the vessel.

### DESCRIPTION OF THE DRAWINGS

The figure illustrates by block diagram, apparatus for performing the method of my invention.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

A basic problem in all decarburization systems is to avoid oxidation of the metallic values such as chromium and iron. There are two consequences of over oxidation of metallics. The first and perhaps most obvious one is the economic loss of the metallic values which must be recovered. The second problem has to do with the overall control of the process. During vacuum decarburization, early over oxidation of the melt leads to the formation of scum or oxide slag which may later combine in an uncontrolled manner with carbon in the melt, leading to uncontrolled eruptions. A close monitoring of the reactions as they occur is necessary to minimize the aforementioned difficulties and this close monitoring is achieved by the method of my invention. The basic objective of the invention is to control the oxidation of carbon from the melt during vacuum processes. The reaction is controlled in a manner such that excessive build up of easily reducible oxides such as iron and chromium does not occur during the decarburization process. In U.S. Pat. No. 3,420,657, it is taught that oxygen or other oxidizers may be added to a melt at a pressure calculated from thermodynamic considerations. It is also taught that the addition of oxygen or oxidizers is terminated when the pressure within the vessel suddenly increases. This teaching presumes that once the thermodynamic considerations are met, the desired reactions will proceed and no kinetic considerations need be applied. I have found that the teaching of the above patent is in error and that a continuing monitoring of the procedure must be affected and controls on the reactions impressed hereon, otherwise undesirable oxidation of certain metallics within the bath will occur. My invention which involves the monitoring of the rate of oxygen blow (or oxidizer input), the output gas composition and the pressure of the system allows more straightforward and complete control of the decarburization process and may be used to avoid oxidation of the metallics within the bath.

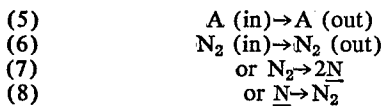
As is known to those familiar with the art, when oxygen, gaseous oxidizers or even solid oxidizers are added to a melt containing carbon, the oxidizers can either react with the carbon in the melt to form gaseous products of reaction, such as carbon monoxide and carbon dioxide, or they can react with other elements within the melt, such as manganese, iron, phosphorus, silicon, chromium, titanium, etc., to form solid oxides. For the purpose of the description of this embodiment, it is assumed that oxygen or oxygen and inert gas mixtures are used as the oxidizers. Where oxygen is the basic oxidizers used, the following reactions may occur:

- (1)  $O_2 + 2C \longrightarrow 2CO \uparrow$
- (2)  $O_2 + C \longrightarrow CO_2 \uparrow$
- (3)  $O_2 = O_2 - (\text{Oxygen by passes the melt})$
- (4)  $\frac{x}{2}O_2 + y \begin{matrix} (Fe) \\ (Cr) \\ (Si) \\ (etc.) \end{matrix} \longrightarrow M_yO_x$

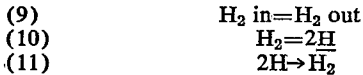
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(where M is a metallic element and MyOx are oxides such as FeO, FeOCr<sub>2</sub>O<sub>3</sub>, Cr<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, etc., which can form).

For the inert or diluent gases

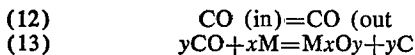


Small amounts of nitrogen will either dissolve in or evolve from the bath).



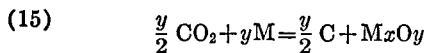
(Small amounts of hydrogen will either dissolve in or evolve from the bath).

If carbon monoxide is used as one of the input gases, the following reactions are possible:



(Where M is a metallic element such as silicon, manganese, chromium, etc.).

Similarly, if carbon dioxide is used as one of the input gases, the following reaction may occur:



From the above reactions, it may be seen that if metallic oxidation is to be avoided, reactions which produce an increase or at least do not produce an alteration in the total gas volume within the vessel are preferred. The reactions to be avoided (which are Equations 4, 13 and 15) are those which cause a decrease in the total gas volume. It will be noted that these are the equations which describe the production of metallic oxides, being those of silicon, manganese, chromium, iron, etc. Ideally, all of the gaseous oxygen introduced into the system will be converted into carbon monoxide. Actually some of the oxygen passes through the vessel unreacted and some of it combines to form carbon dioxide. The uncontrolled oxidation will allow some of the oxygen to go into the form of a solid oxide. It will be noted at this point that even though some of the metallic oxides which are formed may be volatile, such as silicon monoxide, these oxides condense on the cooler parts of the vessel. The net effect upon the total system is that all metallic oxides of concern may be considered as solid oxides.

Thus, whenever a predetermined addition of oxygen (oxidizer) is made to the bath and a determination is made of the average composition of the off gases, it is possible to estimate an overall output of gases by known procedures. This estimated output of gases constitutes either a part or all of the output load that the vacuum pumping system must evacuate. Empirically, it is determined that a capacity of the pumping system increases as the pressure increases. Further, knowledge of the expected load from the decarburization reactions (the estimated output of gases) and the load from any ballast input to the system (supplied to establish a particular desirable pressure for the reaction) enable an estimate of the pressure which should be reached within the system, to be made. This expected pressure may then be compared with the actual measured pressure within the system. If the observed measured pressure within the system is equal or higher than that calculated or expected, it may be concluded that metallic oxidation is not occurring. It will be evident to those skilled in the art that this conclusion is valid when there are no substantial leaks in the system. If the pressure observed or measured is lower than the calculated or expected pressure, metallic oxidation is occurring. The discussion thus far assumes that the decarburization process is to be conducted such that no metal-

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lic oxidation is desired or expected to occur. In practice, small metallic losses can be tolerated and allowances may be made for these by setting minimum efficiency limits for the conversion of oxygen, carbon monoxide, carbon dioxide and oxygen. Efficiency is defined as follows:

(16)

Conversion efficiency in pct.

$$= \frac{100 \times [\frac{1}{2} (\text{Volume CO}) + \text{Volume CO}_2 + \text{Volume O}_2 \text{ as off gas}]}{\text{Volume of O}_2 \text{ injected}}$$

Whenever the actual or observed pressure is less than the expected pressure, corrective action must be taken to avoid or minimize the undesirable oxidation of those metallic values within the bath sought to be retained. The particular corrective action necessary depends upon the status of the system. The fact that the actual pressure is less than the expected pressure suggests that the system pressure is higher than that desirable to support efficient decarburization. It is necessary to decrease the total overall system pressure to one which will support effective decarburization (i.e., one in which loss of metallic values is not experienced). In those instances where both a ballast load and an oxidizer input are being used, the system pressure may be decreased by decreasing the ballast load. Reducing pressure in the system accelerates the decarburization reaction and thus, may reduce the metallic oxidation reactions, thereby reducing the metallic losses. The supply of oxidizer might also be reduced (oxygen), thereby reducing the amount of oxidizer available for the decarburization reaction to a point in which the oxidizer is essentially totally consumed by that reaction, leaving none available for the oxidation of the metallic values sought to be minimized. Likewise, both the ballast supply and the oxidizer supply may be reduced together to accomplish a combination of the above described effects. Upon the observation of an actual pressure less than the expected pressure indicating metallic oxidation, I prefer to reduce the ballast load gradually, comparing the difference between new actual and expected pressures (by computing expected pressure for each new ballast load supplied to the system) until reaching a pressure which the system indicates effective decarburization is occurring. This would be where the system pressure was reduced sufficiently to a point where the actual pressure existing within the vessel equaled or exceeded the expected pressure by calculation of the thermodynamic considerations of the decarburization reaction.

Whenever the system pressure is greater than or equal to the expected pressure from calculation of the thermodynamic considerations, it indicates that the decarburization processes are progressing satisfactorily (i.e., no metallic oxidation is taking place). It is, however, possible that the decarburization system is not being utilized in its most optimum fashion. Thus, for control of the vacuum decarburization process according to system pressure, so long as the actual pressure within the system is greater than or equal to the expected pressure of the calculations, oxidation of the metallic values has been minimized to the degree desired or totally eliminated.

The method of control suggested herein is a dynamic one and may be utilized both in an automatic control system or in a manual manner. The accompanying figure illustrates a vacuum decarburization system where control of the decarburization may be affected by my method. Reference numeral 2 indicates a vessel such as a basic oxygen furnace or a processing ladle containing a bath of molten metal 3 and having a sealed covering 4 attached thereto such that a vacuum may be drawn within the vessel. 2. A supply tube 6 is provided for feeding an oxidizer such as oxygen into the vessel and supply tube 8 is provided for feeding a gaseous ballast load such as nitrogen or argon to the interior of the vessel 2. Connected to the vessel 2 is a vacuum pump such as a steam ejector system

10, capable of providing a vacuum to the vessel 2 to support efficient decarburization of the bath 3 within vessel 2. I prefer to use a double connected steam ejector system having a main line vacuum 12 and a secondary line vacuum line 14 connected to the vessel 2 such as at cover 4. I use the double connection to permit a throttled evacuation of the reaction vessel 2. The steam ejector system 10 I employ is a multiple ejector system having a single first stage 16, a double section stage 18 and 18' coupled directly to the first stage 16 and each of which are connected to a steam condenser 20. A ballast supply 22 is provided to first condenser 20. Third stage ejectors 24, 24' and 24'' are connected to condenser 20 and directly to ejectors 18 and 18'. Third stage ejectors 24 and 25 are individually connected to second stage condensers 26 and 26' which are in turn connected to fourth stage ejectors 28 and 28'. An additional fourth stage ejector 28'' is connected directly to the third stage ejector 24'. All three of the fourth stage ejectors 28, 28' and 28'' are connected to a final stage condenser 30. Ballast is supplied to this system at 22 to assist the establishing of a particular desired pressure within the vessel 2 in conjunction with oxidizer supply at 6. The ballast supply at 8 is conventionally an emergency nitrogen ballast which may be fed directly into the vessel. This same nitrogen ballast system may be used for back-filling the reaction system when the decarburization and other gasing cycles are completed. It is possible to supply the ballast load for regulating the ambient pressure of the system through supply 8 though practical advantage is gained at 22. The decarburization apparatus would also include flow measurement and control devices 32 in the oxidizer supply system being capable of measuring the flow of the oxidizer and control therefor, as well as any inert gases which may be also injected therein. Vacuum pressure gauges will be provided as at 34 to measure the vacuum within the vessel, as well as desirable control points within the steam ejector system such as preceding each ejector stage. Off gas analysis system is provided as is known in the art for measuring the particular off gases and the composition of the off gas according to its components. Likewise as with the flow control and measuring devices at 32, similar flow control and measuring devices are necessary in line 22 as at 36 for the measure and control of the ballast supplied through line 22. Suitable control and measuring means are commercially available and known in the art. It is also preferable to have a computer available to perform the calculation of the decarburization reaction to rapidly provide the calculation of the expected pressure according to the various parameters established within the system.

I claim:

1. In the method of vacuum decarburizing molten metal within a closed vessel wherein oxidizing material is introduced into the vessel and wherein it is desired to minimize the oxidation of certain metal values contained within said metal by establishing a predetermined ambient pressure within said vessel, by measuring the composition and flow rate of input gases to the vessel, and by measuring the composition of the off gases to determine the expected rate of carbon removed from said metal, the improvement comprising: determining the expected pressure within the vessel from a consideration of composition and flow rate of input gases and the composition of off gases; measuring the actual pressure within said vessel; comparing the expected and actual pressures and adjusting said composition and flow rates of said input gases from a consideration of actual and expected pressures to maintain said actual vessel pressure at least as great as said expected pressure.

2. The improvement according to claim 1 wherein maintaining said actual vessel pressure at least as great as said expected pressure includes reducing the quantity of oxidizing material introduced into the vessel while maintaining the flow rate of input gases constant, thereby maintaining a constant ambient pressure within said vessel.

3. The improvement according to claim 1 wherein maintaining said actual vessel pressure at least as great as said expected pressure includes decreasing the ambient pressure within said vessel accelerating the decarburization reaction and thereby reducing oxidation of said metallic values.

4. The improvement according to claim 3 including reducing the quantity of oxidizing material introduced into the vessel.

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75—59, 60, 130.5